background sheet

Models and misconceptions

Models and analogies to explain concepts in electricity

Teachers may use several models or analogies to help explain concepts of charge, current, electrical potential and energy.

1. A water circuit has pipes full of water. A pump pushes water molecules through the pipes, around the circuit, to form a current. This analogy compares a water circuit with an electrical circuit. A conductor contains electrons that are made to move by a power supply, just as water molecules in a water circuit for a pond fountain can be made to flow by a pump.
2. Golf balls in a pipe may be used to demonstrate the instantaneous nature of electron drift in an electrical circuit. If a pipe is filled with golf balls, and an additional golf ball is inserted at one end, then the ball at the other end of the tube instantaneously exits the tube.
3. Water in a pipe may be compared with parallel circuits. A pump pushes a given number of water molecules through a pipe. If the pipe branches into two equal diameter paths then half the molecules will flow into each branch and the number of molecules passing any given point is halved. In a parallel circuit with two branches of equal resistance, the current passing through each branch is half the current measured before it enters the branches. If the pipe branches into different diameter paths then different amounts of water will flow in each branch. In the same way, different currents flow in a parallel circuit with branches of different resistance.
4. A freeway with three lanes of cars travelling at 100 km h^{-1} carries more vehicles than a single lane road with cars travelling at 100 km h^{-1}. Although the speed of all vehicles is constant, the number of vehicles in a three-lane freeway is greater than in a single lane road. This helps explain how current is greater when the cross-section of a conductor is increased.
5. Waterfalls model potential difference (voltage) and current. A large quantity of water molecules passing over a high waterfall models a high potential difference (voltage) and large current. A large quantity of water molecules passing over a low waterfall models a lower potential difference (voltage), but the same current, as in the higher waterfall.
6. A large wheel may be used to model instantaneous transmission of energy in a circuit. The entire wheel turns as a unit. Action at one point is instantaneously transferred to any other point on the wheel, just as action in an electrical circuit instantly affects all other parts of the circuit.
7. A ski-lift provides an analogy for potential difference in series circuits. A lift takes skiers to the top of a mountain where there is higher potential (physical height) than at a halfway point. Similarly, a high voltage battery produces a higher potential difference than a low voltage battery. As skiers descend a mountain they lose potential energy, just as energy used in an electrical circuit causes a battery to go ‘flat’.
8. Economy and business check-in counters at an airport may be used to help explain the drift of charge in resistors in parallel. With a larger number of check-in counters available to travellers in economy, the number of people that can be processed in a given time is greater than in the business queue. If electrons are drifting in a parallel circuit, more electrons will pass through a conductor of less resistance than high resistance. Note: It is the number of travellers, not the speed at which they are processed, that determines the total quantity.

Common misconceptions in electricity

The following statements about electricity are examples of misconceptions, held by students, that may prevent them from fully understanding difficult concepts in electricity.

1. **It is current that flows in an electrical circuit.**

   There is no single substance called 'current'. It is drifting particles carrying charge around a circuit that creates a current.

2. **Charge in an electrical circuit moves at the speed of light.**

   Electrons in an electrical circuit move at much less than the speed of light. Calculations confirm that the drift of charge may vary from 3.6 m s^{-1} to 3600 m s^{-1}, depending on the cross section of the conductor. The electromagnetic field produced by the moving charge does travel at the speed of light.

3. **Electricity is a special form of energy.**

   Electrical energy is composed of waves travelling along columns of electrons inside wires. The energy itself is contained in electromagnetic fields connected to those electrons.

4. **All electric currents are flows of electrons.**

   Electric currents are not just flows of electrons, they are flows of electric charge. If either protons or electrons flow, that flow is an electric current. In saltwater, fluorescent lights, and battery acid, positive ions move, and this flow is an electric current. Electric current in fuel cell membranes is actually a flow of protons.

5. **To create static charge, electrons are transferred from one object to another.**

   Removing electrons from a neutral atom creates static or imbalanced charges. Moving charge within an object also creates this imbalance. Charges being moved can be negative or positive. It is even possible to add or remove protons from some materials, as in fuels cells that use a proton exchange membrane.

6. **Charge that flows in wires comes from batteries and generators.**

   Electric currents in copper wires are a flow of charge, but this charge is not supplied by batteries. Generators do not 'generate' charges — charge already exists in a wire. In copper wire, copper atoms supply the flowing charge. Charge in a circuit is already there before the battery is connected. Batteries and generators supply the potential difference, between two points, that causes charge to move.

7. **Electrons in wires jump from atom to atom during a current.**

   Electrons move between atoms even in the absence of a current. Rather than orbiting single atoms, outer electrons all begin 'orbiting' around and among all atoms in a metal. In an electric current, electrons from atoms in a conductor, drift through the conductor in response to the potential difference across the conductor.

8. **Electricity carries zero mass because electrons have little mass.**

   'Electricity' (meaning charge) has mass because charge is carried by particles that have mass. A flow of charge always requires a flow of carrier particles, so electric current must always carry mass with it. Electric current in a wire is not a flow of energy, it is a flow of matter. For example, ion currents in an electroplating bath are a flow of considerable amounts of matter. Electric currents can transport material.

9. **Humid air is conductive.**

   Electrostatic experiments do not work satisfactorily in humid conditions. This is not because humid air is conductive, but because liquid water droplets can adhere to surfaces of objects. During humid conditions most insulators develop a surface layer of water mixed with contaminants (including dissolved salts). Because this surface layer is conductive, static charge is prevented from building up. Humid air cannot conduct static charge as water droplets in the air are discrete, and usually neutral.